Relevance of initial radioactive heat budgets and the loss of primordial atmospheres for the evolution of Earth-like habitats

Helmut Lammer (Space Research Institute, Austrian Academy of Sciences, Graz, Austria)
Manuel Scherf, Nikolai V. Erkaev, Peter Woitke, Elke Pilat-Lohinger

The initial abundance of radioactive heat producing isotopes of U, Th and K in the interior of terrestrial building blocks and growing protoplanets are important drivers of the thermal developments and the related tectonics of early terrestrial planets and hence their possible evolution to an Earth-like habitat. While U and Th have very high condensation temperatures, K is a moderately volatile element, which can be outgassed from a magma ocean into the surrounding environment. U and Th is mainly lost due to impact erosion, while K can also be lost together with escaping primordial atmospheres. For primordial hydrogen-dominated atmospheres and for magma ocean surface temperatures that are larger than 2500 K, no condensates that fix K are thermally stable, so that outgassed potassium isotopes can populate primordial atmospheres to a great extend. K-isotopes that reach the upper atmosphere can be dragged away by the hydrodynamically escaping hydrogen atoms as soon as the circumstellar gas disk evaporated. The results of our studies indicate that early terrestrial planets will continue their further evolution with a diverse range of radioactive heat producing element abundances. Different initial abundances of radioactive heat producing elements will result in different thermal and tectonic histories of terrestrial planets. The right amount of these elements is necessary for a C-silicate and N-cycle to work well during billions of years. Because such sensitive conditions are required for the origin of life and the evolution of complex aerobic lifeforms, we discuss the connection of the presented findings to the discovery of main atmospheric species with James Webb, future space observatories and large ground-based telescopes such as the EELT.